Preliminary Assessment of Thrust Augmentation of NEP Based Missions

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Extended Abstract

Science Applications International Corporation (SAIC), with support from NASA Marshall Space Flight Center, has conducted a preliminary study to compare options for augmenting the thrust of a conventional nuclear electric propulsion (NEP) system. These options include a novel nuclear propulsion system concept known as Hybrid Indirect Nuclear Propulsion (HINP) and conventional chemical propulsion. The utility and technical feasibility of the HINP concept are assessed, and features and potential of this new in-space propulsion system concept are identified. As part of the study, SAIC developed top-level design tools to model the size and performance of an HINP system, as well as for several chemical propulsion options, including liquid and gelled propellants. A mission trade study was performed to compare a representative HINP system with chemical propulsion options for thrust augmentation of NEP systems for a mission to Saturn's moon Titan. Details pertaining to the approach, features, initial demonstration results for HINP model development, and the mission trade study are presented. Key technology and design issues associated with the HINP concept and future work recommendations are also identified.

In the HINP concept, shown schematically in Figure 1, a fluid propellant is heated with the waste heat from the primary power converter radiator of a nuclear electric propulsion (NEP) system, and expanded through a nozzle to generate thrust, augmenting the NEP system. Compared to more conventional space nuclear propulsion and power systems that have been considered for emerging crewed and robotic space exploration missions (e.g., NERVA, SP-100), this system concept may have some shortcomings in its overall specific impulse performance, mass, and operation lifetime, but it may provide other benefits, including advantages and/or flexibility in development and

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systems integration, containment of radioactive material during operation, and possible enhancement of flight time performance by increasing the effective thrust-to-weight ratio of a NEP flight system, hence reducing trip time.

Other methods, including more conventional chemical propulsion system using liquid and gelled propellants, including O_2/H_2, $O_2/H_2/Al$, NTO/MMH, NTO/MMH/Al, O_2/RP-1, and O_2/RP-1/Al, can also be used to increase the effective thrust-to-weight ratio of a NEP flight system. Chemical propulsion systems can generate high thrust, and have much flight system heritage. Liquid propellants have the highest specific impulse, but (especially for high-performing cryogenic liquids) may have storability issues. In general, solid propellant motors have better storability but lower specific impulse. Gelled propellants may combine the high performance of liquid propellants with enhanced storability.

A preliminary assessment of the various options for thrust augmentation of a NEP system was made by performing a mission trade study for a 100 kWe outer planets-class spacecraft on a mission to Titan, a moon of Saturn. In support of this assessment, an end-to-end HINP system modeling tool was developed and validated. This tool was used to generate system design data, from which mathematical models were developed for mass, size and performance for this class of spacecraft using NEP augmented with a HINP module. Comparable models for chemical-based thrust augmentation modules were developed using published data. The HINP and chemical propulsion models were used in the mission trade study comparing the various propulsion options for high-thrust augmentation of NEP. This paper presents preliminary results from this study, which indicates that thrust augmentation can reduce transit time, but at a penalty of increasing initial mass in low Earth orbit, and compares the relative effectiveness of the HINP and chemical propulsion options. This paper also assesses the technologies required to enable and enhance the HINP concept.

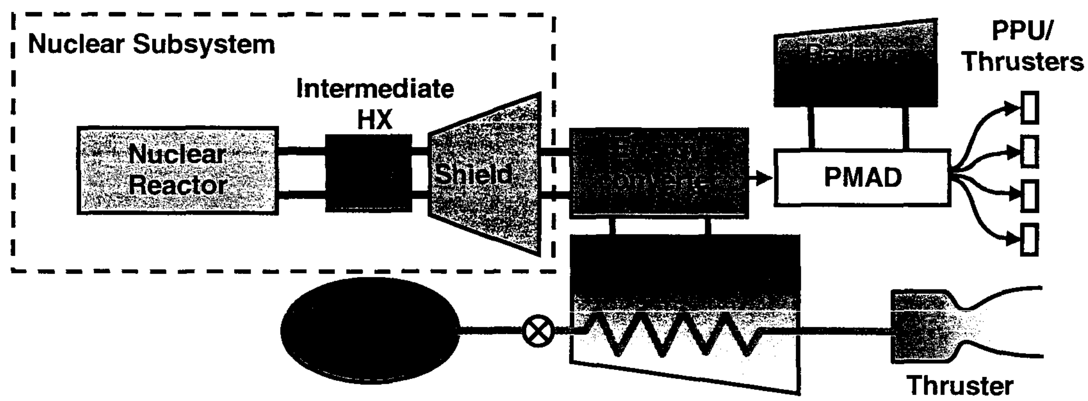

Figure 1. Near-term hybrid INP propulsion system concept – waste heat utilization.